Energy Networks Innovation Process

Annual Project Progress Form

Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form.
Do not use tables

Step 1 - Initial Project Details

Project Title

V2G Dynamic Headroom Control

Project Reference

NGED_NIA_76

Nominated Project Contact(s)

Liza Troshka

Project Start Date

07/2024

Project End Date

01/2026

Scope (15000 Characters max)

Control policies are implemented in V2G devices to effectively avoid excessive voltage rises and to ensure exports remain within thermal limits. Voltage-controlled techniques classified as volt/var or volt/watt characteristics have been trialled by South Australia Power Networks which are designed such that the control policy at the V2G inverters can be pre-configured with each device then operate autonomously thereafter. However, it remains uncertain whether these control policies will achieve the desired objectives with UK LV feeder topologies, or whether the control parameters may need to be modified, either to ensure voltage limits are maintained or to avoid excessive export power constraints. Further work is also needed to determine how the available export power will be constrained and how the impact of these constraints will be shared between the customers.

There is an opportunity to use measured voltage data from smart meters to better inform the control policies implemented in V2G devices. Voltage data can be captured, either on a near-real-time basis to determine whether limits are exceeded, or more likely as a less immediate method using data from previous days or months to determine the available headroom for additional exports while maintaining a high confidence that voltages will remain within range. Aggregated demand data can also be examined to assess the headroom available for additional export power while remaining within thermal limits.

It is still envisaged that the near-term operation of active and reactive power control in V2G devices will be managed autonomously, but with control policies that can be customised for each LV feeder, using settings that are informed by analysis of the available headroom according to the smart meter data. Settings could be updated as a background process, as the number of LCTs with export capability increases, or possibly more frequently if the effects are seasonal or subject to daily variations. It may also be appropriate to define separate control policies for different periods/days of the week, or for specific periods within the day.

This method also allows for the impact of constraints to be shared more equally between the customers on a feeder. This might be via allocation of a fixed export quota, possibly in conjunction with a voltage-based method, or by setting a lower voltage rise threshold for customers that are nearer to the substation. It seems likely that these methods may have some penalty in terms of the total export power that might be achieved, but with the benefit of a fairer distribution of the constraints between customers sharing the same LV feeder.
A recent Royal Society report considering future energy storage requirements estimated that this could rise to 98 GW. This maximum demand will be driven by the electrification of heat, where very much higher ramp rates and peaks are required than at present. Generation from renewable sources will also be intermittent and will likely be scaled to provide the mean annual demand, plus some degree of over-capacity, but will not be sufficient to meet these short term daily peaks. In addition to long-term storage covering seasonal variations in generation, a short-term storage mechanism will be needed to cover intra-day demand variations.

Electric vehicles and V2G are expected to be a key resource to provide this short-term storage. If connections for V2G are not enabled by DNOs then there will be significant costs to the consumer for this short-term storage capability to be provided elsewhere, for example by using large-scale battery parks storage. It is difficult to determine the future cost saving enabled by using V2G, but an indication of the value of storage is provided by the Powerloop project, estimating that customers could earn up to £180/year from participation in the balancing mechanism via an aggregator. Scaling this for 28 million customers suggests a cost saving against the overall short-term storage requirement of £5 billion per year. Clearly this is at current pricing, and the returns may be diluted as more customers enter the market, but the requirements for short-term storage are also expected to increase significantly.

Objective (15000 Characters max)

Key objectives are:

- Evaluate V2G control techniques to understand their effectiveness in maintaining LV assets within operational ranges in a desk-top environment
- Assess the benefits of new techniques where smart meter data is used to customise V2G control methods, varying either with location, time of day, or as the uptake of LCT appliances progresses
- Quantify the impacts on losses of reactive power control techniques
- Assess the impact on customers, in terms of the likelihood and equity of power constraints

Success Criteria (15000 Characters max)

The project will have been successful if the following outcomes are achieved:

- A clear understanding of the expected benefits of different V2G control strategies that are the focus of this study, and in particular of the additional value obtained if control parameters are updated locally and dynamically rather than being pre-set equally on all devices. This would lead to the specification of control algorithms that can be assessed in a future trial using real V2G devices on live LV feeders.
- A clear understanding of the optimum level of control interaction, where improvements in power exports and customer experience fairness are balanced against increased communication overhead.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims, Objectives and Success Criteria

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria. (15000 Characters max)

Please see below an update for relevant project objectives identified above:

- Evaluate V2G control techniques to understand their effectiveness in maintaining low voltage (LV) assets within operational ranges in a desk-top environment.
    - The initial simulation study has been undertaken and intended to assess control techniques that mitigate voltage rise due to power exported to the grid from electric vehicle batteries. The modelling considered the development of low carbon technologies (LCTs) on LV substation and LV feeders. An initial baseline model considered the LV feeders with existing demands, followed by a second model where solar photovoltaics (PV), heat pumps and electric vehicles (EVs) are added. This model uses the distribution future energy scenarios (DFES) to estimate a likely uptake of these appliances for a selected future year of 2035. The model then adds vehicle-to-grid (V2G) operation, taking an extreme assumption that all EV chargers participate in an export event, such as might be arranged via a supplier or aggregator to support a sudden loss of generation, or the loss of an interconnector on the wider grid. For the purposes the initial simulation, it is assumed that every EV charger has a vehicle connected such that power can be supplied back to the grid. This event is timed in the early afternoon when exports from solar PV are already high and demand from other appliances will be lower.
    - The initial simulation results (Deliverable 1.3 report) are summarised below:
        - Volt-watt control successfully reduces RMS substation currents and mean losses, although this is at the expense of a reduction in the overall level of exported power and so is undesirable from a system perspective, even if helpful in regard to LV capacity constraints.
        - Volt-var control reduces worst-case voltage rise, but by a lesser extent than volt-watt control.
        - Further work is needed to understand the impact of unbalance, as the control methods tend to operate asymmetrically where all the EV chargers on one phase have a higher voltage. This effect is accentuated by the non-linear nature of the ramped volt-watt and volt-var functions such that EV chargers on one phase may be fully constrained or not affected at all. The resulting unbalance can also lead to increased voltage deviations on other phases.
        - The demand due to recharging has a significant impact on voltage ranges and could be a greater concern than the power exports, particularly where the rated import power is higher than the export power.
        - A randomised delay has been proposed to mitigate the impacts of synchronised recharging. This would also need consideration in future volt-watt control standards.
        - The impact of the constant-power load model needs further investigation.
        - Simulations so far have assumed a nominal substation busbar voltage of 245 V, based on previous experience of substation monitoring in the Losses Investigation. This voltage lies within the ramp range for volt-var control and so, some reactive power is consumed even in nominal conditions. Since reactive power is already being consumed in the nominal case, there is less additional reactive power than can be added when the voltage increases.
    - Assess the benefits of new techniques where smart meter data is used to customise V2G control methods, varying either with location, time of day, or as the uptake of LCT appliances progresses
        - Modelling work will proceed in the remaining timeframe of the project by incorporating smart meter data in the analysis. Further update will be provided once this piece of work is complete (Work package 2).
    - Quantify the impacts on losses of reactive power control techniques
        - As indicated above, Volt-watt control successfully reduces RMS substation currents and mean losses, although this is at the expense of a reduction in the overall level of exported power and so is undesirable from a system perspective, even if helpful in regard to LV capacity constraints.
    - Assess the impact on customers, in terms of the likelihood and equity of power constraints
        - This aspect of the project has not been addressed at the time of writing this report. Further information to follow.

Required Modifications to the Planned Project Approach During the Course of the Project

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate. Please confirm if no changes are required. (15000 Characters max)

The time allocations for Work Package 1 and 2 have been expended due to:1) some minor delays with smart meter data provision; 2) additional changes required in the modelling software which were identified during the course of Work Package 1.

The delays identified above do not impact the overall timeframe or budget of the project.

Lessons Learnt For Future Projects

Recommendations on how the learning from the Project could be exploited further. This may include recommendations on what form of trialling will be required to move the Method to the next TRL. The Network Licensee should also state if the Project discovered significant problems with the trialled Methods. The Network Licensee should comment on the likelihood that the Method will be deployed on a large scale in future. The Network Licensee should discuss the effectiveness of any Research, Development or Demonstration undertaken. (15000 Characters max)

The key lessons learnt from Work Package 1: Simulation Study are:

- Initial results suggest that volt-watt control is more effective than volt-var control in limiting extreme voltage deviations. The models so far assume that all EV chargers participate in V2G export events for a half-hour period around midday when PV exports are also high and when demand is low. EV chargers do not participate in the export event if they are already charging. Applying volt-var control has so far demonstrated less of a reduction in voltage rise than volt-watt control. From the network perspective, volt-watt control is more effective.
    - This finding has set the directions for WP2. In particular, the project will aim to understand whether modifications to the volt-var control method could improve effectiveness, or whether it will be effective if more appliances, such as PV inverters, can also participate.
- The simulation results indicate that exported power on one phase causes voltage rise on that phase, but if exports are unbalanced, will cause voltage drops on other phases. Similarly, high loads on one phase can cause voltage rise on other phases. Where exports are unbalanced, the non-linear nature of volt-watt control can cause exports on one phase to be constrained more so than on other phases and this can accentuate unbalance.
    - This observation has set directions for WP2. Highlights the impact of phase unbalance, particularly where volt-watt or volt-var control is applied at specific thresholds, creating a non-linear behaviour.
- The simulation model currently assumes that recharging from V2G export events takes place immediately after the half-hour export period has ended. Since exports are assumed limited to 3.68 kW, and imports may use the full rated 7 kW, the impact of the recharge for voltage drop may be more significant than the impact of the exports on voltage rise.
    - This finding has set directions for WP2. Further discussion with stakeholders and ideally also aggregators will help to understand how the customers may recharge EV batteries after a discharge event.
- In initial models, no diversity was applied in the timings of the recharge periods. Where volt-watt control is applied, export powers are reduced relative to the permitted 3.68 kW export power. These power reductions occur throughout the half-hour export period. As a result, the total exported energy is reduced by the volt-watt control. There is a corresponding reduction in the energy needed for recharging. However, the model currently assumes that this reduction allows for the duration of the recharge period to be reduced rather than moderating the recharging power. As a result, although the volt-watt control can mitigate voltage rise during the export periods, it does not mitigate voltage drop during the recharge periods. The model has demonstrated a scenario where the exports on two phases were entirely switched off due to volt-watt control, such that they had no requirement for recharging. This resulted in significant unbalance during the recharging period, with a high voltage drop on the phase with EV chargers that had continued to export. This also caused a voltage rise on the other phases.
    - This highlights the need for a diversified approach to the recharging after a V2G export event. Exports are necessarily coordinated in response to either a requirement for grid support or a common tariff. However, the timing of recharging can be diversified. This is particularly necessary where recharging uses a higher power than permitted exports.
- Although volt-watt control is more effective from the network perspective, this is achieved through a greater reduction in the exported energy. There is therefore a reduced benefit to the wider grid from V2G, likely associated with reduced revenue to the individual customers providing exports. Volt-var control provides less mitigation of voltage rise but does so without any significant impact on the exported energy.
    - This fairness of constrained exports will be addressed together with the use of smart meter data.
- The models have assumed V2G export powers being limited to 3.68 kW, whereas EV charging imports are at 7 kW. Assuming that the power electronics therefore has a rated power transfer capability of 7 kVA, volt-watt control with reactive power at 60% of the inverter capacity, as in TS129, can be accommodated without any reduction in active power.
    - Modelling in Work Package 2 will look at combined volt-watt and volt-var control.
- Modelling has also included scenarios where a diversity factor was applied to the recharging after V2G export events. This is very effective in mitigating the worst-case voltage drop caused if all participating EV chargers replace the exported energy as soon as the export event has ended. V2G implementations would ideally be designed so that either i) recharging at full import power is diversified, or ii) synchronised recharging uses a lower power to allow for the combined impact of nearby devices recharging at the same time.
    - The diversified approach will be prioritised in future modelling as the non-diversified method creates severe short-term voltage drops that would not be acceptable for network operation within voltage limits
- The market for grid support services from V2G may become saturated if the number of participating devices becomes very large. In this case, customer revenue may be more likely to arise from demand peak-shaving and arbitrage. V2G would then be more likely to export in the evening peaks, and typically exports would only occur once the import demand had already been met. Exports are therefore determined by the residual energy once these demands have been met. The voltage rise impact of V2G exports is expected to be much less in this scenario as the exports will be more diversified and would occur at times when local demand from customers without EV chargers is also expected to be high.
    - The modelling will still consider the grid support event as a worst-case scenario for voltage rise, but consideration of the impacts on fairness need to reflect that any inequality in the scope for exports is mitigated by the reduced contribution of

Outcomes of the Project

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these outcomes it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

As indicated throughout this report, there are moderate benefits that can be achieved by employing volt-watt and vot-var control techniques but further investigation is needed to provide firm conclusions.

The final results and recommendations, including considerations for further trials, will be provided upon completion of the project and in the next ENA annual Summary Report.

Step 3 - Outputs And Implementation

Data Access Level & Quality Details

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. This requirement may be met by including a link to the publicly available data sharing policy. (15000 Characters max)

Monthly update on the project progress is available here: National Grid - V2G Dynamic Headroom Control

Any further detail can be requested through the NGED Innovation mailbox: nged.innovation@nationalgrid.co.uk

Foreground IPR

A description of any foreground IPR that have been developed by the project and how this will be owned. (15000 Characters max)

The following is a list of Foreground IPR expected to be generated as a result of the project:

- Volt/watt and volt/var V2G control parameters optimised for UK feeders
- Temporal and feeder-based V2G parameters for volt/var and volt/watt control
- Methods to define capacity headroom based on smart meter data
- V2G modelling simulation tools comprising a power-flow analysis with added customisation to model LCT demand and V2G operation
- Novel demand modelling approach using smart meter voltage data to characterise impact of existing demands and superposition of voltage drops due to anticipated future demands
- Applicability of V2G control methods to UK networks
- Optimisation of V2G control methods in regard to fairness, capacity and exports

The above list of IPR is expected to be owned by Loughborough University.